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ScienceDirect
Energy Procedia 61 (2014) 2026 – 2029
Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

Analysis of the Burnout Time of Superfine Pulverized Anthracite Coal during Combustion in Industrial Boiler

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Abstract

A model for the combustion of superfine pulverized anthracite coal in industrial boiler combustor was built, and by taking Yangquan anthracite coal and 3 Fujian anthracite coal as specific objects, the burnout time of these pulverized anthracite coal with different particle sizes of 20～75μm under a range of ambient temperatures was calculated. Research shows that: The burnout time of Fujian anthracite of particle size between 20～75μm is 0.5～2.5s at the ambient temperature of 1100℃, and that of Yangquan anthracite of particle size between 20～75μm is 0.3～1s at the ambient temperature of 1200℃.
Keywords: Anthracite; superfine pulverized coal; industrial boiler; burnout time

1. Introduction

The reserves of anthracite are massive in china, but anthracite can't combust efficiently in conventional pulverized coal boiler or small scale CFB boiler for its low volatiles. Superfine pulverized coal has larger specific surface area than pulverized coal's, which improves the combustion characteristics of anthracite greatly [1], making high efficiency anthracite combustion in industrial boilers possible. By taking superfine pulverized Yangquan anthracite and 3 Fujian anthracite with different particle sizes(< 125μm) as research objects, their burnout time under a range of ambient temperatures was calculated. The results have great reference value for selecting suitable range of coal fired in industrial boilers and reconstructing burners of existing pulverized coal boilers.

2. Numerical Model

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Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.12.067

2.1. Assumptions

A model for the combustion of an anthracite particle is built using the following assumptions [2]:

- The combustion reaction takes place on the surface of particles. As the reaction progresses, the burning surface moves towards the core of a particle. Ignoring erosion among particles, there will be an ash shell at the external layer of the particle with the same diameter as the original one. The shrinking core combustion model is shown in Fig 1.
- The combustion is first-order reaction; primary reaction product is CO and CO_2. Ignore the combustion in the inner pore region of a particle.

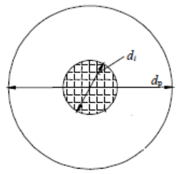

Fig.1 Schematic of the shrinking core combustion model of superfine pulverized anthracite coal particle

2.2. Mass balance equations and energy balance equations

Mass changing rate of a char particle [3] is given by

$$-\frac{dm_i}{d\tau} = M_C \pi d_i^{\,2} K_i \beta C_{\infty,O_2} \tag{1}$$

Where $m_i=(\pi\rho d_i^3)/6$ is the particle mass; d_i is the carbon sphere diameter; K_i is the combustion rate; $C_{\infty,O2}$ is the ambient oxygen concentration; $\beta=4/3$, C/O_2 molar ratio.

The energy balance equations of a single char particle [2] is given by

$$mc_p \frac{dT_P}{d\tau} = -\frac{dm_i}{d\tau} Q_{dw} - hF(T_p - T_g) - \sigma\varepsilon_p \varphi_{pw} F(T_p^{\,4} - T_w^{\,4}) \ (T_w = T_g) \tag{2}$$

3. The selection and calculation of parameters related to the numerical model and selected coal's correlation model parameters

3.1. The combustion rate of a char particle

K_i is the combustion rate of a char particle [2, 3, 4] which is given by

$$1/K_i = 1/K_0 + 1/K_{O_2} \tag{3}$$

$$K_0 = k_0 T_p \exp\left(-E/RT_P\right) \tag{4}$$

$$K_{O_2} = Nu_d \cdot D/d_i, \ (Nu_d=2) \tag{5}$$

$$D = \left(0.59 - 120\left(\frac{d_0 - d_i}{2}\right)\right)1.482\left(\frac{T_g}{273}\right)^{1.81} \cdot 10^{-5} \tag{6}$$

3.2. Convective heat transfer coefficient in char combustion

Convective heat transfer coefficient of a char particle [5] is given by

$$h = {Nu \cdot \lambda_p}/{d_p} \ , \ (Nu \approx 2) \qquad (7)$$

3.3. Selected coal's correlation model parameters

Taking Yangquan (YQ) anthracite and three representative Fujian anthracite—Longyan(LY) anthracite, Tianhushan (THS) anthracite, Yong'an (YA) anthracite as research objects, coal parameters [6] related to model calculation are shown in Table 1.

Table 1. Some corresponding parameters of anthracite used in calculations

	ρ_p/kg·m^{-3}	Q_{dw}/kJ·kg^{-1}	E/ kJ·mol^{-1}	k_0/m·(s·K)$^{-1}$	λ_p/m·(s·K)$^{-1}$
LY	1750	21565	224	3.13×1010	0.25
THS	1880	22168	201	3. 2245 ×108	0.23
YA	1850	21163	182	5.4125×107	0.22
YQ	1500	20218	117	37289	0.23

4. Results and Discussions

The burnout time of these pulverized anthracite coal with different particle sizes of 20～75μm under ambient temperatures of 1223～1473K was calculated, as shown in Figure 4～Figure 7.

A comparison of Figure 4～Figure 6 shows that, the burnout time of Fujian anthracite of particle sizes between 20～30μm, 30～50μm, and 50～75μm, are about 2.26～3.69s, 3.39～6.15s, 5.65～9.25s respectively at the ambient temperature of 1000℃; they're about 1.06～1.86s, 1.59～3.12s, 2.66～4.70s respectively at the ambient temperature of 1050℃; they're about 0.53～0.99s, 0.79～1.66s, 1.25～2.52s respectively at the ambient temperature of 1100℃. The burnout time of Fujian anthracite of particle size between 20～75μm is about 0.28～1.44s at the ambient temperature of 1150℃ and it's about 0.15～0.86s at the ambient temperature of 1200℃.

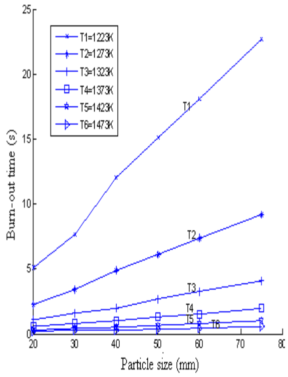

Fig. 4 Particle sizes vs Burnout time of LY anthracite

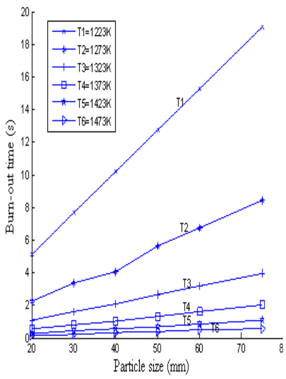

Fig.5 Particle sizes vs burnout time of THS anthracite

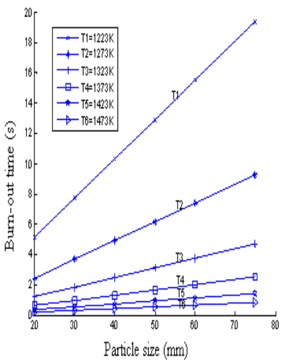

Fig.6 Particle sizes vs burnout time of YA anthracite

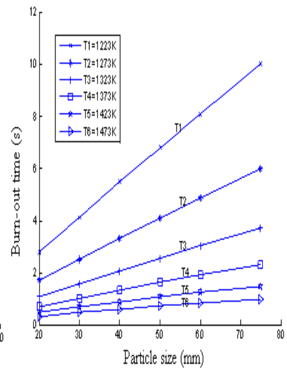

Fig.7 Particle sizes vs burnout time of YQ anthracite

Figure 7 shows that, the burnout time of Yangquan anthracite of particle size between 20～30μm, 30～50μm, and 50～75μm, are about 1.69～2.50s、2.50～4.09s、4.09～5.98s respectively at the ambient temperature of 1000℃; they're about 1.06～1.57s、1.57～2.55s、2.55～3.69s respectively at the ambient temperature of 1050℃; they're about 0.69～1.01s、1.01～1.62s、1.62～2.30s respectively at the ambient temperature of 1100℃. The burnout time of Yangquan anthracite of particle size between 20～75μm is about 0.46～1.46s at the ambient temperature of 1150℃; it's about 0.31～0.97s at the ambient temperature of 1200℃.

5. Conclusions

Since Fujian anthracite has poor combustion reactivity and a low ash fusion temperature（< 1100℃), its burnout time can be shortened by decreasing particle sizes and improving furnace temperature; while Yangquan anthracite's combustion reactivity is relatively better and its ash fusion temperature is high, it has a wide range of furnace temperatures and particle sizes selected for combustion in industrial boilers. Based on the residence time of pulverized coal in an industrial boiler, the proper pulverized coal particle sizes and furnace temperatures can be chosen by referring to their burnout time calculated.

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Biography

Zhao Long-fei is a laboratory technician in school of mechanical and energy engineering, Jimei university. He received an engineering master from Jimei university in 2013. Currently, his main research subjects are in combustion and energy utilization.